Summary of the context and overall objectives of the project

The AIDA-2020 project brings together the leading European infrastructures and academic institutions in detector development for particle physics, a field attracting a global community of more than 10,000 scientists. In total, 19 countries and CERN are involved in this programme, which follows the priorities of the European Strategy for Particle Physics closely. With the upgrade of the Large Hadron Collider (LHC) and the preparation of new experiments, the community will have to overcome unprecedented challenges in detector technology to ensure the success of these endeavours.

AIDA-2020 advances detector technologies beyond current limits by offering well-equipped test beam and irradiation facilities for testing detector systems under its Transnational Access (TA) programme. Common software tools, microelectronics and data acquisition systems are also provided. This shared high-quality infrastructure ensures optimal use and coherent development, thus increasing knowledge exchange between European groups across the boundaries of the various future projects. The enhanced coordination within the European detector community leverages EU and national resources, and contributes to maintaining Europe's leadership in the field.

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

The kick-off meeting and first Annual Meeting, held at CERN and DESY, respectively, were organised within work package **WP1 (Management and Coordination)**. Attended by about 140 participants each, the meetings highlighted the start-up of the initiative. During the project, progress is monitored in bi-monthly video meetings of the Steering Committee (SC), where WPs take turns to report at every other instance. Administrative actions include the distribution of the EC pre-financing and monitoring of resource utilisation.

Activities in **WP2 (Innovation and Outreach)** began with the launch of the project website and intranet, and a project newsletter, named “On Track”. Videos on the facilities offered under the AIDA-2020 Transnational Access programme have been filmed. A technology landscape report was delivered, giving insight into the domains of detector technology where dissemination from research to industry is highest. The call for proposals for the Proof-of Concept fund returned 11 good proposals for innovative projects to realize the impact of detector research on society.

A major milestone was achieved with a first prototype batch of industrially produced silicon strip sensors on 8-inch wafers; representing the largest silicon strip detector elements ever built.

In **WP3 (Advanced Software)**, the enhancements of the geometry software package DD4hep were brought to immediate use by the linear collider and FCC communities. It has additional functionality such as the DDG4 component, which provides a tight coupling to the Geant4 and DDAlign packages and allows for the simulation of misaligned detector geometries, The Pandora particle flow algorithms have been extended to also be applicable for neutrino interactions in LAr TPCs and work has started on track fitting on massively parallel architectures.

In **WP4 (Microelectronics and Interconnections)** preparatory steps were made towards providing CMOS readout chips for new instrumentation under development. The work includes the design and successful test of 65 nm demonstrator prototype CMOS chips for the pixel detectors in WP6 and WP7. The 130 nm TSMC CMOS technology was selected for the gaseous detectors and calorimeters in WP13 and WP14 after extensive simulation studies. The through silicon via (TSV) for interconnecting the pixel sensors have been etched and show good test results.

Substantial convergence on an approach to distribute timing and synchronisation signals between different detectors has been achieved in **WP5 (Data Acquisition System for Beam Tests)**, and a new trigger and logic unit (TLU) was designed and built. The EUDAQ software developed under EUDET and AIDA has been selected as the common platform and is being expanded towards scalability, event building and monitoring. The technical specifications of the interfaces to the common DAQ system have been documented following a community consultation.

WP6 (Novel High Voltage and Resistive CMOS Sensors) has organised several meetings and a workshop for the knowledge transfer on TCAD and Geant4 simulations. Generic test structures for technology evaluation were designed and produced, and demonstrator sensors have been under test since February 2016. First functional large area HV/HR-CMOS assemblies with capacitive interconnections to the readout chip have been constructed. Excellent detection efficiency and time resolution were measured in beam tests. Various technologies for hybridisation are under study.

TCAD simulations for the optimization of the small size 3D and planar pixel cells were performed in **WP7 (Advanced hybrid pixel detectors)** and their results were implemented in the design of prototyping sensor runs on thinned substrates. Several prototyping runs, including the first manufacturing of thin 3D and Low Gain Avalanche Detectors (LGAD) sensors on 6” wafers, were completed towards the preparation of the Multi-Project Wafer (MPW) runs in 2017.

The activities of **WP8 (Large Scale Cryogenic Liquid Detectors)** are embedded in the infrastructures provided by the neutrino platform at CERN. Key technologies for purity monitoring, photo-detection, charge readout, associated cryogenic front-end electronics and DAQ, were reviewed and further developed. A very high voltage system for 300 kV was developed and tested for the study of high field phenomena in noble gases. Many of these systems have been integrated in the 3x1x1 m^3 prototype detector, which will be soon filled with liquid argon to take cosmic data.

Challenges of low material budget designs of future track and vertex detectors are addressed in **WP9 (New Support Structures and Micro-channel cooling)**. Standard micro-fabrication technologies for silicon cooling devices have been consolidated with prototypes, and alternative advanced processes, potentially less expensive and with higher production yields, are being explored. Important progress has been made in the field of miniaturized high-pressure hydraulic connectors, an essential component for their future integration in complex detectors. Specifications for a facility to characterise mechanical support structures have been defined.

The Transnational Access programme is organised in **WP10 (Beam Test Facilities), WP11 (Irradiation Test facilities)** and **WP12 (Detector Characterisation Facilities)**. WP12 contains new test facilities offering ion micro-beams for the characterisation of radiation damage effects, and equipment for electromagnetic noise characterisation. All facilities started promptly, including those which were not present in AIDA, and the user support has in general met or even exceeded expectations, demonstrating the success of the programme and the demand from the community. A panel including independent representatives is supervising the selection procedures.

A wide community joins their research activities in **WP13 (Innovative Gaseous Detectors)** to develop the tools to produce and characterise resistive plate chambers (RPC) and micro-pattern gas detectors (MPGD). Studies were made to test alternatives for gases with high global warming potential. The use of interferometric methods to control mechanical tensions was demonstrated, and novel MPGD architectures and tools for laboratory studies have been developed in view of technology transfer for the production of gaseous detector components to industry.

WP14 (Infrastructure for Advance Calorimeters) unfolds synergies between the efforts to develop highly granular calorimeter systems for the LHC upgrades and future linear colliders. Several milestones were reached with the establishment of test systems for scintillator-based readout or irradiated silicon sensors and LHC-oriented electronics, including the demonstration of an assembly chain for silicon calorimeters and the design of cooling systems for tungsten / carbon fibre and hadron calorimeter structures.

Activities to enhance the test beam and irradiation services at European facilities are progressing in **WP15 (Upgrade of Beam and Irradiation Test Infrastructure)**. A transport system for neutron irradiation of large samples at JSI has been designed and installed. A new version of the highly demanded EUDET-type pixel telescopes has been constructed and installed. The specifications for an online user and sample management system for the IRRAD facility, the installation of the common slow control system at DESY, the design of a cold box for irradiation campaigns, the evaluation of low cost silicon material for fluence monitoring and the design of an upgraded cosmic tracker for the GIF++ facility at CERN have all been achieved.

Thanks to the experience and efforts of the WP coordinators, all Networking and Joint Research Activities reached full speed quite quickly and proceed well in line with the initial schedule.

Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)

AIDA-2020 builds on the achievements of the previous initiatives EUDET and AIDA, e.g. existing test beam infrastructures like magnets, pixel telescopes or software frameworks, but it goes beyond in many respects. There are a wider range and new types of infrastructures, and stronger support for TA to them, and there are new topics, like novel silicon sensor concepts or micro-channel cooling technologies. Particular attention is paid to, and a special PoC fund is devoted to, the cooperation with European industry, e.g. for the production of silicon devices of large area, and the transfer of technologies for developing applications outside of particle physics, e.g. for medical imaging.